



## NOISE FILTERING AN IMAGE SEQUENCE

## BACKGROUND OF THE INVENTION

## Field Of The Invention

[0001] The invention relates to noise filtering an image sequence. The invention further relates to encoding an image sequence, wherein the image sequence is noise filtered.

## Description Of The Related Art

[0002] It is well known that image sequences generally contain noise that may arise either during the initial stage of image acquisition, or during the processing and transmission operations, or even during the storing stage. This noise not only degrades the quality of the sequence but also the performance of subsequent possible compression operations (e.g., MPEG, wavelet, fractal, etc.). For these reasons, there is great interest in reducing the noise as much as possible without unacceptably affecting the image quality.

[0003] To reduce the noise, a filtering operation is necessary. Such a filtering operation may result in blurring and 'ghost' effects in the image, resulting in an unacceptable quality for the viewer. This is due to the fact that almost all images have detailed areas, with edges, contours, etc.

SUMMARY OF THE INVENTION

[0004] An object of the invention is to provide advantageous filtering. To this end, the invention provides a method and device for noise filtering an image sequence, and a method and device for 5 encoding an image sequence.

[0005] In a first embodiment of the invention, statistics in at least one image of the image sequence are determined, and at least one filtered pixel value is calculated from a set of original pixel values obtained from the at least one image, wherein the original 10 pixel values are weighted under control of the statistics. The invention provides a simple method to perform an adaptive filtering, which is preferably applied in a pre-processing stage of a compression system. Statistics may be easily obtained from the at least one image by any known (or yet unknown) calculation, e.g., 15 variance or correlation (or approximation thereof) in a (sub-set) of the at least one image.

[0006] In a further embodiment of the invention, the step of calculating comprises weighting the set of original pixel values under control of the statistics to obtain a weighted set of pixel 20 values, and furnishing the weighted set of pixel values to a static filter for calculating the at least one filtered pixel value from the weighted set of pixel values. This embodiment has, inter alia, the advantage that adaptivity of the filtering is obtained by using a separate weighting step, and that a static filter is used in 25 combination with the weighting. Instead of using a variable filter,

which implementation is more complicated, the invention provides a simple adaptation of the pixel values which, in combination with a static filter, results in adaptive filtering.

[0007] Advantageously, the statistics include a spatial spread and/or temporal spread of the set of original pixel values. In this embodiment, the adaptation is based on the computation of a 'spread' of the pixel values that are processed to obtain a filtered pixel value. The spread is a measure based on differences between pixel values, the spread being preferably computed as a sum of absolute differences, a given absolute difference being obtained by subtracting an average pixel value from a given original pixel value. The local 'spread', i.e., the spread of the set of original pixels from which a filtered pixel value is calculated, is a good indicator of the local activity of the image. In this way, on the basis of the statistics of the pixels that are processed, it is possible to control locally the strength of the filter in order to prevent annoying artifacts where the image content is critical, e.g., on the edges. In pre-filtering, i.e., before entering a coding loop, defects around the moving objects and, in particular, the moving edges are eliminated by means of the adaptivity, based on the local statistical properties of the images in order to accomplish spatial filtering and also spatio-temporal filtering capable of being strongly effective against white Gaussian noise, without producing unacceptable artifacts in the image sequence.

This is especially true when averaging filters are applied. Median filtering reduces both Gaussian and spiky noise.

[0008] Advantageously, the weighted pixel values are obtained by taking, for each pixel in the set of original pixels, a combination 5 of a portion  $\alpha$  of the original pixel value, and a portion  $1-\alpha$  of the central pixel value. In fact,  $\alpha$  indicates the amount to which the original pixel values take the value of the central pixel value. In case,  $\alpha = 0$ , all original pixel values have the same value as the central pixel value, i.e., the original pixel values 10 other than the central pixel value are not taken into account. This is preferably the case when the local spread is high. In case  $\alpha = 1$ , all original pixel values keep their the original value. This is preferably the case when the local spread is low. In general, the higher the spread, the lower the value of  $\alpha$ . In this embodiment, 15 the control signal consists of only one value, i.e.,  $\alpha$ , so that the implementation can be kept as small as possible.

[0009] The local spread is preferably furnished to a look-up table, whose output controls the weighting. A look-up table provides a simple and fast way of controlling the weighting.

20 [0010] Preferred filtering operations in the present invention include median filtering and averaging filtering. When spread in temporal direction is used, e.g., in a spatio-temporal averaging filtering, it is preferred to use a second look-up table for the temporal direction, because pixel values in temporal directions are 25 often differently correlated to each other than pixel values in

spatial directions. Further, pixels in the temporal directions are less correlated to pixels in the spatial directions. Therefore, it is advantageous to lessen the weight of neighboring pixels in the temporal directions in the total result in comparison to pixel values in the spatial directions.

[0011] In case a temporal direction is used, the temporally displaced original pixel values preferably include two original pixel values from different fields (with unequal parity) in a same frame and at least one original pixel value of a previous frame. This embodiment saves memory compared to storing pixel values of fields with same parity in different frames, because in the latter case, at least two frames need to be stored to have two fields available.

[0012] Further, filtered temporally displaced pixel values may be used rather than temporally displaced original pixel values to reduce bandwidth requirements of the implementation of the filter.

[0013] U.S. Patent 5,621,468 discloses a motion adaptive spatio-temporal filtering method which is employed as a pre-filter in an image coding apparatus, which processes the temporal band-limitation of the video frame signals on the spatio-temporal domain along the trajectories of a moving component without temporal aliasing by using a filter having a band-limitation characteristic according to a desired temporal cutoff frequency and the velocity of moving components.

[0014] U.S. Patent 4,682,230 discloses an adaptive median filter system, which filters samples of an input signal. Further circuitry estimates the relative density of the noise in the input signal to generate the control signal supplied to the adaptive median filter.

5 The adaptive filter selectively substitutes the sample having the median value for the current sample. If the current sample/median distance exceeds the processed inter M-tile distance, then the median valued sample is coupled to the output, and otherwise, the current sample is coupled to the output. M-tile is a generic term  
10 relating to the relative position of a sample in a list of samples sorted according to their value. The median and upper and lower quartiles are special cases indicating values one-half, three-quarters and one-quarter of the way through the ordered list, respectively. The inter M-tile distance is the difference between  
15 the upper M-tile value and the lower M-tile value and is a measure of the contrast of the image in the locality of the current sample.

[0015] U.S. Patent 5,793,435 discloses de-interlacing of video using a variable coefficient spatio-temporal filter. The interlaced video signal is input to a video memory, which, in turn, provides a  
20 reference and plurality of offset video signals representing the pixel to be interpolated, and spatially and temporally neighboring pixels. A coefficient index, transmitted with the interlaced video as an auxiliary signal, or derived from motion vectors transmitted with the interlaced video, or derived directly from the interlaced  
25 video signal, is applied to a coefficient memory to select a set of

filter coefficients. The reference and offset signals are weighted together with the filter coefficients in the spatio-temporal interpolation filter, such as a FIR filter, to produce an interpolated video signal. The interpolated video signal is 5 interleaved with the reference video signal, suitably delayed to compensate for filter processing time, to produce the progressive video signal.

[0016] The aforementioned and other aspects of the invention will be apparent from and elucidated with reference to the 10 embodiments described hereinafter.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the drawings:

[0018] Fig. 1 shows an embodiment of an encoder according to the 15 invention;

[0019] Fig. 2 shows input samples of adaptive filters as shown in Figs. 3 and 4;

[0020] Fig. 3 shows an embodiment of an adaptive spatial median filter according to the invention;

20 [0021] Fig. 4 shows an embodiment of an adaptive spatial averaging filter according to the invention;

[0022] Fig. 5 shows a first set of input samples of an adaptive spatio-temporal averaging filter as shown in Fig. 6;

[0023] Fig. 6 shows an embodiment of a spatio-temporal averaging 25 filter according to the invention; and

[0024] Fig. 7 shows a second set of input samples of an adaptive spatio-temporal averaging filter as shown in Fig. 6.

[0025] The drawings only show those elements that are necessary to understand the invention.

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#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Fig. 1 shows an embodiment of an encoder 1 according to the invention, comprising an input unit 10, a computing unit 11, a look-up table 12, a weighting stage 13, a filter 14 and an encoding unit 15. An input video signal  $V_1$  is furnished to the encoder 1 and received in the input unit 10. In computing unit 11, a local spread  $S$  is obtained from a set of original pixel values indicated by  $P_t$ ,  $M_i$ . The result of the spread computation is furnished to the look-up table 12 to obtain a control signal  $\alpha$ . In the weighting stage 13, the pixel values  $P_t$ ,  $M_i$  are weighted to obtain weighted pixel values  $P_t$ ,  $N_i$ . The weighted pixel values  $P_t$ ,  $N_i$  are filtered in the filter 14 to obtain a filtered pixel value  $P_t'$ . A plurality of pixel values  $P_t'$  constitute a filtered video signal. According to advantageous embodiments of the invention, the filter 14 includes a spatial median filter, a spatial averaging filter, a spatio-temporal averaging filter, or a combination of these. The filtered video signal, constituted of the plurality of filtered pixel values  $P_t'$ , is encoded in the encoding unit 15 to obtain an encoded video signal  $V_2$ . The encoding unit 15 is preferably an MPEG encoder.

[0027] Fig. 2 shows exemplary input samples of an adaptive filter according to the invention, e.g., a spatial median filter as shown in Fig. 3 or a spatial averaging filter as shown in Fig. 4. These input samples may also be used in a preferred example of 5 input samples within one field. Dotted lines indicate image lines of a first field and continuous lines indicate image lines of a second field of a frame. A sample  $P_t$  is at a position of a calculated output sample. To calculate one filtered luminance sample, five samples  $P_t$ ,  $M_1$ ,  $M_2$ ,  $M_3$  and  $M_4$  are used as input. In an 10 MPEG encoder, which is a preferable field of application of the invention, horizontal color sub-sampling has normally already taken place at the input, according to the CCIR 4:2:2 format. Therefore, a horizontal distance between color samples ( $P_{tc}$ ,  $M_{1c}$ ,  $M_{2c}$ ,  $M_{3c}$  and  $M_{4c}$  for U&V) is twice as large as for the luminance samples. 15 Because experiments indicated that extra gain from the color samples is minor, color median processing can be skipped without significantly losing quality.

[0028] Median filtering per se is known in the art for its capability of preserving monotonic step edges, and is therefore 20 widely used for two-dimensional image noise smoothing. The implementation of a median filter requires a very simple digital non-linear operation: a sampled and quantized signal of length  $n$  is taken; a window that spans  $m$  signal sample points is slid across the signal. The filter output is set equal to the median value of 25 these  $m$  signal samples and is associated with the sample at a

center of the window. The median of  $m$  scalar  $X_i$  with  $i = 1, \dots, m$  can be defined as the value  $X_{med}$  such that, for all  $Y$ :

$$\sum_{i=1}^m |X_{med} - X_i| \leq \sum_{i=1}^m |Y - X_i| \quad (1)$$

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[0029] In order to obtain a unique value as a result,  $m$  must be an odd value. Suppose a random sample  $\{X_1, \dots, X_m\}$  from a population having a bi-exponential density function described by the expression:

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$$f(x) = \frac{\gamma e^{-\gamma|x-\delta|}}{2} \quad (2)$$

where  $\gamma$  is a scaling factor and  $\delta$  is a maximum location parameter. The value of  $\delta$  maximizing the likelihood function:

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$$L(\delta) = \prod_{i=1}^m \frac{\gamma e^{-\gamma|x_i-\delta|}}{2} \quad (3)$$

is called the maximum likelihood estimate for  $\delta$ , based on the random sample  $\{X_1, \dots, X_m\}$ . By taking a logarithm of (3), it can be shown that the maximum likelihood estimate is clearly equal to  $Med[X_1, \dots, X_m]$ . The median is thus an optimal estimate of the location parameter in the maximum likelihood sense, if the input distribution is double exponential as in (2). In a similar manner, an average is the maximum likelihood estimate for a Gaussian distribution.

- [0030] Conventionally, when the median filter is used for two-dimensional images, the intensity at every point in the image is replaced by the median of the intensity of the points contained in an  $m*m$  window centered at that point. It is known that the median filter is more effective than a linear filter for smoothing images with spiky noise distribution, because outliers are rejected by the median filtering. According to the properties mentioned above, the median filter tends to produce lower variances for the filtered noise when the distribution of the input noise has larger tails (e.g., spiky noise), but has lower performances then, e.g., an averaging filter in case of uncorrelated (white) image noise with a Gaussian distribution; also when either Gaussian or impulsive noise are present, the latter is not completely suppressed as when only impulsive noise is present.
- [0031] It has already been said that median filters are attractive for their capability of preserving monotonic step edges (width  $(m+1)/2$ ) in the images, while an averaging filter tends unavoidably to blur edges, but is more effective against Gaussian noise. In an embodiment of the invention, a simple and easy implementation in real hardware is obtained by using a separable median filter. Such a separable filter performs median filtering operations by means of successive applications of one-dimensional median filters along different directions. Although the result is not identical to the full two dimensional median filter (using an  $m*m$  window), it can be seen that the separable filter provides

comparable performances to the two-dimensional median filter. However, the main advantage is that in the full two-dimensional median filter, the center element is the median of  $m^2$  points; by performing the median of  $m$  points separately along rows and 5 columns, a computational saving factor can be achieved. Separable median filters as such are known in the art.

[0032] Although the median has a good capability of preserving edges, if it is applied directly on the image data, strange effects can occur as blurring and 'tails' or 'shadows' around moving parts. 10 Inter alia, in order to minimize these undesired effects, the present invention provides an adaptive median filter, this filter being adaptive on the basis of local statistics of the image.

[0033] Fig. 3 shows an embodiment of an adaptive median filter according to the invention. The input samples  $P_t$ ,  $M_i$ , as shown in 15 Fig. 2, are furnished to a computing unit 21 and to a weighting stage 23. In the computing unit 21, a spatial spread  $S_{\text{spat}}$  is calculated from the input samples, this spread  $S_{\text{spat}}$  being furnished to a look-up table 22. Based on the spread  $S_{\text{spat}}$ , a control signal  $\alpha$  is obtained from the look-up table 22. The control 20 signal  $\alpha$  is furnished to the weighting stage 23, in which the input pixel values  $P_t$ ,  $M_i$  are weighted to obtain adapted pixel values  $P_t$ ,  $N_i$ . Note that in this embodiment, the central pixel  $P_t$  is unaffected by the weighting. In median filter 24, a median is taken 25 from the adapted pixel values  $P_t$ ,  $N_i$  to obtain a filtered pixel value  $P_t'$ . The median filter 24 comprises three separate median

filters 240, 241 and 242. These separate median filters 240, 241, 242 together form a total median filter. The operation of this embodiment is discussed below.

[0034] A spatial spread  $S_{\text{spat}}$  of the five input samples  $P_t$ ,  $M_1$ ,  
5  $M_2$ ,  $M_3$  and  $M_4$  is computed as follows:

$$M_{\text{ave}} = \frac{(P_t + M_1 + M_2 + M_3 + M_4)}{5} \quad (4)$$

$$S_{\text{spat}} = \frac{\text{abs}(M_{\text{ave}} - P_t) + \sum_{i=1}^4 \text{abs}(M_{\text{ave}} - M_i)}{4} \quad (5)$$

10 The output of the spread of the luminance is translated, via the look-up table 22, into the control parameter  $\alpha$  for the weighting stage 23. In a preferred embodiment, the content of the look-up table 22 is downloadable from an external source. An exemplary  
15 look-up table 22 is given by:

$$\begin{aligned} S_{\text{spat}} > 10 &\Rightarrow \alpha = 0.5 \\ S_{\text{spat}} > 15 &\Rightarrow \alpha = 0.35 \\ S_{\text{spat}} > 20 &\Rightarrow \alpha = 0.2 \end{aligned} \quad (6)$$

Adapted pixel values are then obtained by:

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$$\begin{aligned}
 N_1 &= \alpha M_1 + (1 - \alpha) P_t \\
 N_2 &= \alpha M_2 + (1 - \alpha) P_t \\
 N_3 &= \alpha M_3 + (1 - \alpha) P_t \\
 N_4 &= \alpha M_4 + (1 - \alpha) P_t
 \end{aligned} \tag{7}$$

From these adapted pixel values, the median is computed in the  
5 filter 24 according to:

$$P'_t = \text{Med}[\text{Med}(N_1, N_2, P_t), P_t, \text{Med}(N_3, N_4, P_t)] \tag{8}$$

As will be easily understood by those skilled in the art, the  
10 median is alternatively obtained by:

$$P'_t = \text{Med}[N_1, N_2, P_t, N_3, N_4] \tag{10}$$

[0035] An advantage of a median filter according to the  
15 invention, e.g., the median filter 24 as discussed above, is that a  
gradual filtering is obtained around the edges so that annoying  
effects in the sequence are avoided, or, at least, attenuated. When  
the spread  $S_{\text{spat}}$  is larger, i.e., high spatial activity, e.g.,  
around edges, then  $\alpha$  is smaller so that the original central pixel  
20 is assigned a higher weight and the filtering of the median filter  
24 is weaker.

[0036] Fig. 4 shows an embodiment of an adaptive spatial  
averaging filter according to the invention. Computing unit 31 and  
look-up table 32 are similar to computing unit 21 and look-up table  
25 22 as shown in Fig. 3. The look-up table 32 is coupled to a

weighting stage 33, in which the input samples  $P_t$ ,  $M_i$  are weighted to obtain adapted pixel values  $P_t$ ,  $N_i$  that are furnished to a spatial averaging filter 34.

[0037] As stated before, a spatial averaging filter is the maximum likelihood estimate for the Gaussian distribution. Since noise present in video sequences is usually a sum of effects due to different sources (acquisition, pre-amplifying, amplifying, transmission and handling operations), it can be assumed in a lot of cases that the noise distribution is Gaussian (theorem of the central limit). In these cases, an averaging filter is preferred. By using an adaptive averaging filter according to the invention in a pre-filtering stage of an encoding arrangement, effective noise filtering is obtained which results in a significant bit-rate reduction. However, it is necessary to pay attention to the quality of the resulting image, since blurring of the spatial and temporal edges unavoidably occur. An object of the invention, in relation to averaging filters, is to control such blurring in order to achieve an acceptable quality for the filtered sequence. For an adaptive spatial averaging filter, the adaptivity based on local statistical properties (spread/activity) of the image can be exploited as it has been described for the median filter. The result is an adaptive spatial averaging filter, which better preserves the quality of the images.

[0038] Computation of the adapted pixel values is similar to the computation previously described in relation to the adaptive median

filter. Also, in this case, the filtering of the chrominance may be skipped, because its contribution to the final result is minor.

[0039] An output of the adaptive spatial averaging filter is computed as follows:

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$$P_t'' = \frac{(N_1 + N_2 + N_3/2 + N_4/2 + P_t)}{4} \quad (11)$$

It is noted, that the pixels  $N_3$  and  $N_4$  are divided by a factor 2 to reduce their weight in the final average because their distance to  $P_t$  is double compared to  $N_1$  and  $N_2$ , since the filtering is applied within a field, and are therefore 'less correlated'.

[0040] When a very low level of noise is present, the image looks obviously much smoother than the original; anyway, by means of a proper adjustment of the look-up table, this effect can be statically controlled, achieving a good trade-off between the noise reduction and the good quality of the video sequence.

[0041] Fig. 5 shows input samples in both spatial and temporal directions in which  $t$  denotes time. In frame  $F_0$ , a set of pixels  $P_t$ ,  $M_i$  is taken, similar to the luminance pixels in Fig. 2. In addition, in this embodiment, pixel values  $P_{t1}$  and  $P_{t2}$  are taken from fields with the same parity in both a previous frame  $F_{-1}$  and a future frame  $F_1$ . Here, a window of seven pixels is considered: five pixels of the present field, one pixel of the previous field with same parity and one of the future field with same parity. It is advantageous to include filtering operations in the temporal

direction, because both spatial and temporal noise are often present. A reduction of the level of noise can be useful for motion estimation either, provided that the motion estimation itself is thought and realized strictly related with the pre-processing part 5 and consequently no too much affected by the increased smoothness of the filtered image, otherwise the quality of the motion vectors can be worse, resulting in some additional coding noise that compromises the final result.

[0042] Fig. 6 shows an embodiment of a spatio-temporal averaging filter according to the invention. In order to reduce annoying effects, such as 'tails', 'shadows' or simply blurring in moving objects, an adaptation step is used in order to perform an effective and not image-damaging averaging spatio-temporal filtering. Also, in this case, the adaptivity is based on the local 15 statistical properties of the image, even if it is now necessary to make a distinction between the pixels belonging to the same field and the pixels belonging to the previous or the next field with same parity. The embodiment comprises a computing unit 41 for computing a spatial spread which is similar to computing units 21 and 31 as shown in Figs. 3 and 4. The computing unit 41 is coupled 20 to a look-up table 43. In this exemplary embodiment, a spread of the pixels belonging to the same field ( $P_t, M_i$ ) and a spread of the pixels ( $P_t, P_{t1}, P_{t2}$ ) belonging to different fields with same parity are separately computed. In other words, the computation of the 25 spread in spatial directions is separated from the computation of

the spread in the temporal directions. For computing the temporal spread  $S_{temp}$  the embodiment comprises a second computing unit 42.

[0043] The temporal spread is computed as follows:

$$5 \quad P_{t,ave} = \frac{(P_t + P_{t1} + P_{t2})}{3} \quad (12)$$

$$S_{temp} = \frac{abs(P_{t,ave} - P_t) + \sum_{j=1}^2 abs(P_{t,ave} - P_{tj})}{2} \quad (13)$$

The result of the temporal spread is translated via a temporal look-up table 44 into a control parameter  $\alpha'$  necessary to perform weighting operations on the temporal pixel values  $P_t$ ,  $P_{t1}$  and  $P_{t2}$ .

[0044] After the computation of the control parameters  $\alpha$  (spatial) and  $\alpha'$  (temporal), the weighting operation is performed in both the spatial and temporal direction, in the spatial direction according to the formula (7) and in the temporal direction according to:

$$WP_1 = \alpha' P_{t1} + (1 - \alpha') P_t \\ WP_2 = \alpha' P_{t2} + (1 - \alpha') P_t \quad (14)$$

20 Finally, an output of the spatio-temporal averaging filter 47 is computed according to:

$$P_t''' = \frac{(N_1 + N_2 + N_3 / 2 + N_4 / 2 + P_t + WP_1 / a + WP_2 / a)}{4 + 2/a} \quad (15)$$

[0045] Note that the weighted pixel values  $WP_1$  and  $WP_2$  are divided by a control parameter  $a$ . The control parameter  $a$  is obtained from a look-up table 45 and is a number  $\geq 1$ , depending on the local temporal spread in the three pixels  $P_t$ ,  $P_{t1}$  and  $P_{t2}$ : the higher the spread, the higher  $a$ , so that the weight of the previous and the next pixel in the average is smaller. By adjusting the look-up table 45 properly, it is possible to control the strength of the filter in the temporal direction in order to achieve a good quality of the image, once again exploiting the adaptively to the image temporal content so that annoying effects connected with edges blurring are reduced.

[0046] The described filter belongs to the class of Finite Impulse Response (FIR) filters. The FIR structure requires keeping in memory the present  $F_0$ , the future  $F_1$  and the previous  $F_{-1}$  original frames for the filtering operation. In order to save memory, it is preferred to use pixels of past fields and with unequal parity, as shown in Fig. 7. In this case, only the present  $F_0$  and the previous frame  $F_{-1}$  have to be stored. This allows a reduction of the memory size as far as the implementation of the filter is concerned, without significantly affecting the resulting quality of the filtered image. Instead of previous original frames, previous filtered frames may be used. In the case that for previous frames in Fig. 7, filtered frames are taken, an Infinite Impulse Response (IIR) filter structure is obtained. This structure has advantages regarding memory usage and bandwidth.

[0047] Examples of devices that encode an image sequence, in which noise filtering according to the invention is applied, are: MPEG-2 encoders, digital video recorders (e.g., DVD-video recording, digital-VHS, HDD VCR), etc.

5 [0048] Adaptive filters according to this invention may also be applied inside a motion-compensating coding loop. Advantageously, an adaptive filter is used in a pre-filtering stage in combination with a temporal filter within the coding loop.

10 [0049] In an embodiment of the invention, at least two adaptive noise filters are combined, e.g., a spatial median filter and an adaptive spatial averaging filter, wherein the filtering is controlled by characteristics of the image sequence. A noise estimator may be added that analyses the level of the present noise. Such a noise estimator is an interesting tool to control the 15 adaptive filters. Advantageously, the noise estimator is arranged to identify the statistical properties of the present noise in order to opportunely switch dynamically between the median and the spatial and/or spatio-temporal averaging filter.

20 [0050] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word 'comprising' does not 25 exclude the presence of other elements or steps than those listed

in a claim. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In a device claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

5 [0051] In summary, noise filtering an image sequence is provided wherein statistics in at least one image of the image sequence is  
10 determined and at least one filtered pixel value is calculated from a set of original pixel values obtained from the at least one image, wherein the original pixel values are weighted under control of the statistics.